Pitting Corrosion for Nuclear Applications and Carbonation Modeling for Reinforced Concrete Applications

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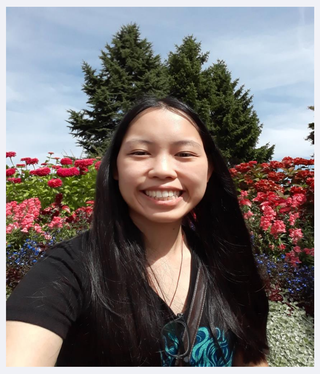

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Research Area

The research area for this project was related to corrosion. Radioactive waste is stored in facilities, usually near the coast. The environment and mechanical loading can lead to stress corrosion cracking over time. The purpose of this research was to evaluate pitting corrosion. However, COVID-19 lead to a change in plans since undergraduate students are not allowed in research laboratories. Therefore, the analysis shown here is related to modeling the behavior of reinforcing steel exposed to atmospheric conditions.

Main Motivation or Background

Last year, during the fall semester, I took the material class with Dr. Rincon Troconis. Finding the class interesting and enjoying her lectures I decided to work in her lab and applied to this internship. In terms of the technical motivation, reinforcement corrosion affects civil construction, causing both economic and human losses. Several cases of carbonation-induced corrosion in reinforced concrete structures have been reported. Carbonation in the concrete surrounding rebar, causes a drop in aqueous solution pH, leading to uniform rebar corrosion and production of corrosion products at the rebar surface. These can crack and spall the concrete cover because of expansive actions of such corrosion products. Therefore, modeling the behavior of this phenomena will help professionals in charge of constructions design the reinforced concrete structure for a long time exposure. The objective of the second part of this project was to analyze data collected during almost six years of natural exposure of concrete specimens at urban sites in 9 iberoamerican countries, by using Neural Network Methods, which has not been used before taken in consideration tropical and non-tropical environments.

Objectives

1. Test the material used to store radioactive waste under different humidity conditions (before COVID-19).
2. The present study objective was to analyze data collected during almost six years of natural exposure of concrete specimens at urban sites in 9 Iberoamerican countries, by using Neural Network Methods, which has not been used before taken in consideration tropical and non-tropical environments.

Methodology

Nuclear related project:
*T*he specimens were polished using 400, 600, and 800 sandpaper on a grinder and polishing machine (Figure 1). Then 4 small indentions were made using the Rockwell hardness machine. A diamond tip was also used to mark the specimens. Samples were cleaned using ethanol then dried and stored inside desicator to prevent corrosion of the surface. Testing was starte by placing samples inside controlled environments with varying relative humidity (RH) values and placing either a sea salt artificial solution or a magnesium solution on the surface.

Fig. 1
Grinder and Polishing Machine

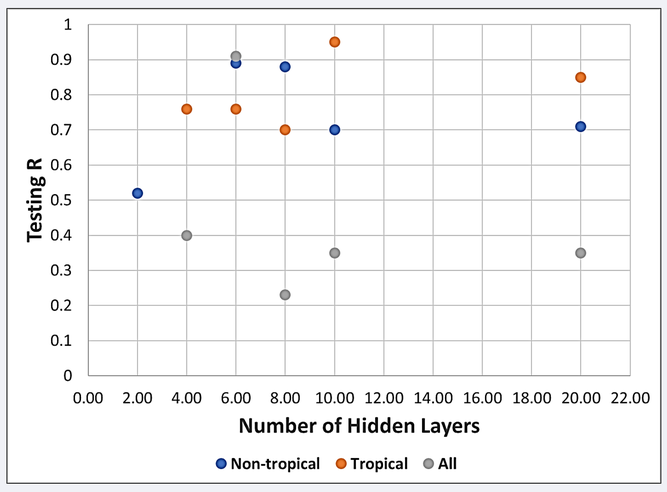
Rebar Corrosion Modeling:
MATLAB was used to evaluate different neural network configurations to model the behavior of reinforcing steel exposed to different rural/urban from tropical and non-tropical locations. For this purpose, 'nftool'[1] was used to calculate the correlation coefficient (R) when modeling all the data together, tropical data and non-tropical data. The testing algorithm and the number of hidden networks were varied.

The input variables were RH, time of wetness, temperature, CO_2, rain fall, capillary absorption and CaO cement content. The output variable was carbonation depth. This data was obtained from the DURACON project[2].

Results

Nuclear Project:
The pitting corrosion test results were not collected nor evaluated since undergraduates had no access to the laboratories (COVID-19). The experiment was finished by Tasnia Fatima (PhD student).

Rebar Corrosion Modeling:
The R values found through modeling had a lot of variability for training, testing and validation. Nevertheless, it was found that the algorithm that presented the testing with the highest strength of linear relationship between input and output variables (R value closer to 1) was the Bayesian Regularization (Figure 2) method when modeling the data for tropical and non-tropical regions separated and when modeling all the data. The algorithm type had a higher effect on R than the number of hidden layers.
On another note, the Bayesian Regularization algorithm only presented three graphs (validation missing), while the other two methods had four. That method only had the training, test, and all R value graphs, missing the validation R graph. The Scaled Conjugate Gradient algorithm presented the worst overall R values for the non-tropical regions.



Skills and Experience

Use of the polishing/grinder, and Rockwell hardness machine was required. Training on the Large-Scale Testing laboratory was also performed since there were plans to participate on fracture mechanics testing under the supervision of a PhD student. Basic chemistry skills was used in the corrosion lab, while MATLAB was used remotely during the COVID-19 quarantine. As a junior the understanding of materials and numerical methods was helpful.

What I Learned

Through this internship I learned different skills related to experimental and modeling approaches related to corrosion.

- How to use the 'nftool' in the computer program Matlab.
- The type of polishing it requires to prepare a sample before pitting corrosion testing.
- Reading the RH required and mixing solutions to achieve the RH goal in the controlled environment.

Future Plans

I have not yet decided which field of mechanical engineering interests me. I plan on applying to internships related to my field of study to narrow the choices and see what I would like to do after graduating.

Acknowledgments

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References

[1] www.mathworks.com/help/deeplearning/ref/nftool.html?s_tid=srchtitle
[2]O. Troconis de Rincón and coauthors, DURACON Collaboration. "Concrete Carbonation in Ibero-American Countries DURACON Project: Six-year Evaluation" CORROSION Journal. Vol. 71, No. 4. Abril, 2015